Insulation of Telephone Wire with Paper Pulp*

By J. S. LITTLE

A method has been developed for economically manufacturing insulated wire for telephone exchange area cable by making the paper on the wire. Further, this method has made it possible to increase the number of wires in a full sized cable by 175% over the number in use in 1914. Developments now under way indicate that suitable insulation can be made to replace certain textiles in some classes of wire and that the use of this process may therefore be still further extended in the not so distant future.

Introduction

IN 1887 the leading telephone engineers attempted to standardize telephone cables and specifications, finally deciding upon # 18 B & S gauge wire covered with two wrappings of cotton and twisted into pairs. A maximum cable size of 52 pairs in a two-inch diameter cable sheath 97% lead, 3% tin, and $\frac{1}{8}''$ thick was permitted under the specifications. The grounded capacity of such cable was 0.20 mf. per mile. In 1891 the Western Electric Company had made successful application of manila rope paper as insulating material for dry core cable and by drying this paper immediately before covering with lead by the newly developed extrusion process the core could be kept dry without the old impregnation with hot paraffin. A great improvement in electrical properties resulted from this change, the electrostatic capacity dropping to approximately one-half its former value. The use of manila paper made from old rope from this time on grew in use for insulating purposes (Fig. 1). The telephone demand was increasing all the time, and since the supply of old rope depended in a large measure on maritime sources of supply the price began to increase. Improvements in telephone instruments, together with increased demand for telephones, permitted the use with economy of more and more pairs of finer and finer wires in a given diameter of cable. This trend can be readily seen if we follow the change in maximum number of pairs used at different dates. In 1888—50 pairs of 18-gauge wire were used, 1896—180 pairs 19-gauge, 1912—909 pairs 22-gauge, 1914—1212 pairs 24-gauge, 1928—1818 pairs 26-gauge, and in 1939—1515 pairs 24-gauge and 2121 pairs 26-gauge (Fig. 2). The increasing number of wires demanded thinner and thinner and better and better paper. As the cable demand increased, increased insulating speeds were necessary to aid in keeping down the cost

* Reprinted, with minor changes, from *Wire and Wire Products,* October 1939.

due to the higher priced papers. Increased flexibility of paper without sacrificing strength and greater uniformity were required in these new thinner papers. Considerable time and money were spent in attempting to reduce the amount of manila fibre due to its price and increased scarcity and to substitute cheaper fibres of wood and cotton. It was finally found that mixtures of 45% rope, 40% wood and 15% cotton could be used for all

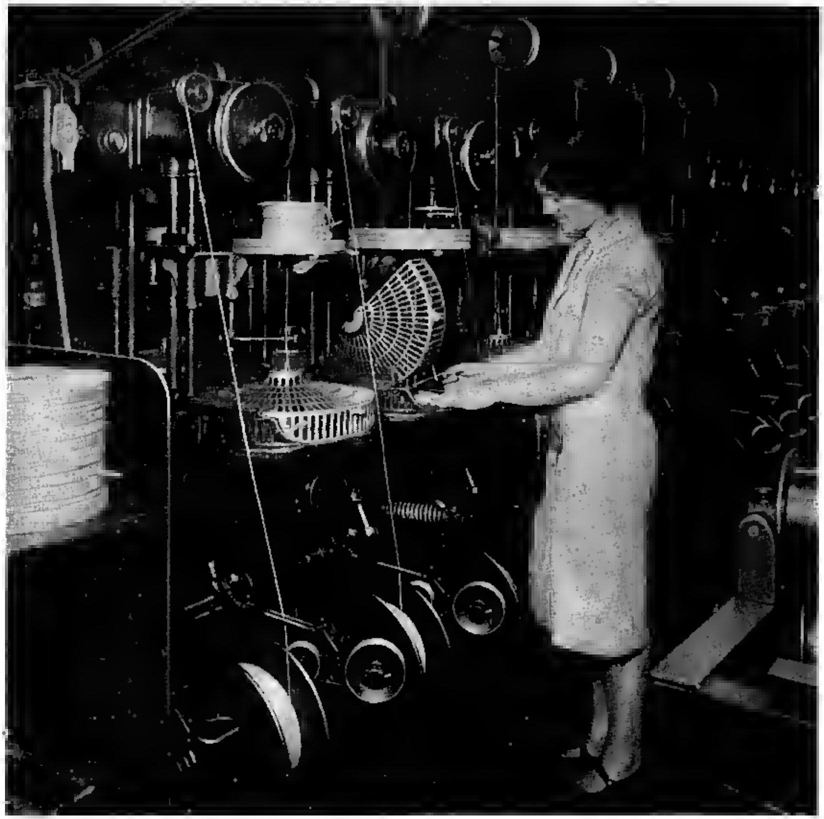

Fig. 1—Paper strip insulating machine

but the very finest insulating papers and that as high as 80% wood and 20% manila rope could be used for the coarser wrapping papers.

In spite of these changes and the improved paper making technique developed by the industry the use of paper $\frac{1}{4}''$ x .0025″ for insulating 26-gauge wire was not entirely satisfactory from a manufacturing point of view. About 1920 some of our engineers began developing the idea of manufacturing the paper right on the wire. If this were possible there

seemed to be no reason electrically why wood pulp would not make a suitable insulating material, and from the mechanical standpoint many of the difficulties involved in wrapping the insulation would be eliminated.

Fig. 2—Comparison of 1212 (left) and 2121 (right) pair cables

The Development of Pulp Insulation

Pulp Machine

The first crude experiments on insulating wire with pulp were done by pouring a suspension of pulp over a wire backed up by a fine mesh screen and after the water was drained away lifting the wire up together with whatever fibers clung to it and then rolling the wire on a flat surface. These samples gave an idea of the type of product to be expected and looked so interesting that a study of equipment and methods was authorized. It developed that the machine most adaptable for our purpose was the standard single cylinder paper machine in use in the paper making industry.

The essentials of this machine are a vat for holding a thin pulp suspension and a hollow cylinder covered with fine mesh screen immersed in the vat. Suitable dams at the ends prevent the pulp suspension passing into the interior of the cylinder. As this cylinder rotates on its axis the water flows through the screen and deposits pulp on its surface. This pulp mat is then picked up by an endless felt belt which is brought into contact with the surface of the cylinder by means of a soft rubber roll which presses it firmly against the pulp mat on the surface of the cylinder. The pulp mat adheres

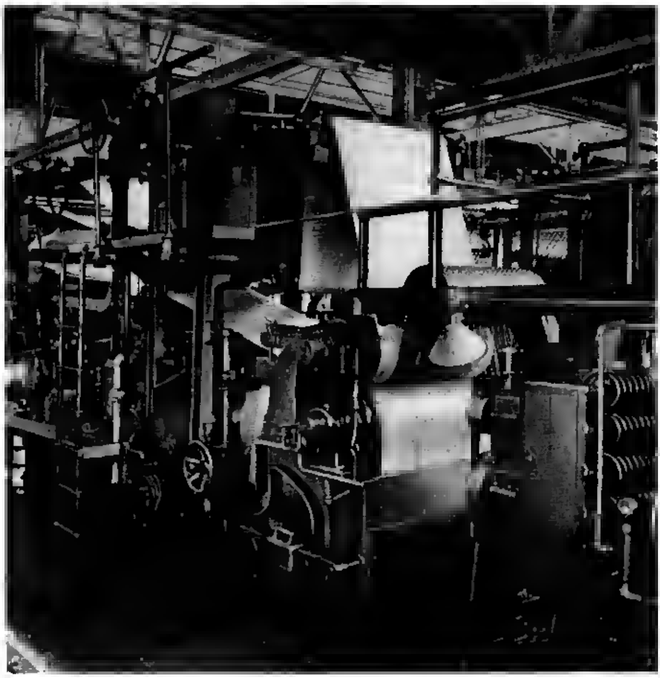

Fig. 3—Forming end of pulp insulating machine

to the felt and together they travel over suction rolls and through squeeze rolls where the excess water is removed. The fibers are thus firmly pressed together so that a sheet of wet paper is formed. After drying and calendering the paper appears in its usual form.

The idea of embedding a wire in the sheet as the pulp was deposited on the cylinder formed the basis of the present development. Usually the paper machines produce a continuous sheet eight or nine feet wide so that it became necessary to devise ways and means of producing sheets only about one quarter inch wide to supply the necessary material for insulating

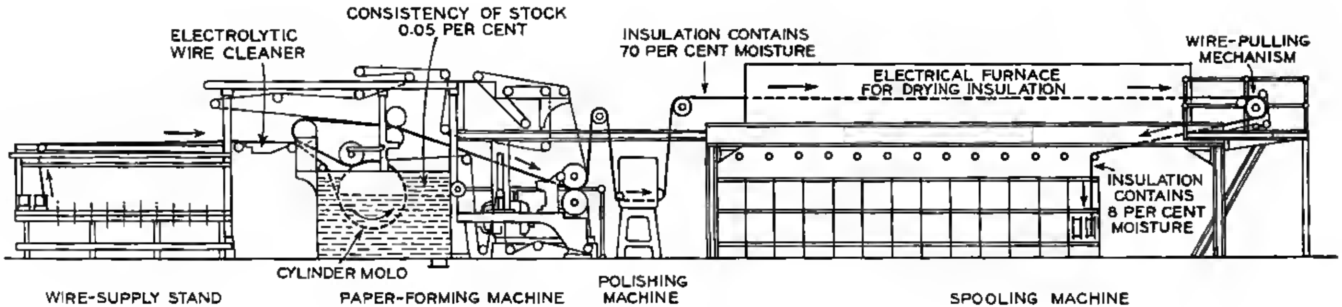

Fig. 4—Schematic of pulp process

wires of 22-gauge and smaller. The most practical size of commercial machine (Fig. 3) was no less than three feet wide hut by painting annular rings on the cylinder screen surface the effect of a series of small cylinders all immersed in a single vat could be produced. This was the scheme finally adopted for preparing the paper making machine and we have standardized on a cylinder three feet long with enough rings to simultaneously produce sixty sheets of paper approximately $\frac{1}{4}''$ in width. The layout of the resultant machine is shown schematically in Fig. 4.

Pulp Supply

Kraft pulp is among the toughest of the wood fibers as well as one of the cheapest. It is prepared by an alkaline process and our experience indicated that this process produced pulp of a greater degree of permanence than the acid processes unless special treatments were used. The chief drawback to its use was its color, brown or tan, which necessitated a change in the color code in the cables. Fortunately, cable designs could be made using fewer colors than had previously been employed so that this obstacle was not serious. Standard paper making beating equipment was purchased and used for preparing the pulp to form the sheets although special beating technique for our purpose had to be developed. The older beating method consists of grinding the fibers in the presence of water under a heavy roll. By this continuous maceration the pulp is softened and fibrilated and made suitable for paper making. The longer the grinding the more parchmentlike the final paper becomes, and as we desire as porous a paper as possible it is necessary to control the beating to a point where good strong paper will be made but will still contain a high degree of porosity. Within the last few years a continuous beating system has been developed to replace the original batch system. In this method the pulp mixed with water is run through a preliminary hydrofiner grinder where the pulp is partially beaten before being stored in a large tank. From this tank it is then fed to the various machines and colored by adding the proper dye. A further refiner in the line to each machine finishes the beating for the particular insulation being made in that position. Study showed that fiber from different sources of wood supply handled differently so that standardization of sources of supply had to be made and methods of test developed to check on new fibers or new sources of pulp.

Due to the small thin sheets made on the machine, the amount of pulp required per unit of time is extremely small. No commercial means of measuring such quantities accurately had been developed and it was necessary to spend considerable time in this study. The suspension of pulp to be measured contains only 1.5% fiber and this is further diluted to .05% in the machine vat. The actual quantity of liquid measured is about 8 gallons

per minute. The device most recently adopted is similar to the jaws of a pair of pliers held between two stationary guides. As the jaws are separated more liquid flows through them and as they are closed the flow is cut down. A vernier scale adjustment makes close and accurate settings possible when used with a constant head. In the older system the dye for coloring the pulp is added in the beater but the newer system more recently put to use in the Kearny, New Jersey Plant supplies the dye as needed so that only uncolored pulp need be stored in tanks and color changes can be rapidly made with little loss of stock.

Wire Supply

A machine of this size and difficulty of control necessitated a continuous supply of wire to avoid large losses in junk and lost time. It was necessary to devise methods of continuous feed, and to do this wire supplied on spools was utilized. On the earliest machines spools 8″ x 8″, containing sixty pounds of bare copper wire, were used, the wire being removed over the head of the spool by means of a flier. At each supply position two spools were placed side by side and a flier placed on one. When the first spool was emptied to the last few turns, an operator, by means of a special hook, pulled out one turn and brazed it to the outer end of the other spool. A flier was then placed on the second spool, and when the braze was reached the transfer to the new spool took place.

Using the new 400-pound spools from the new Kearny Wire Mill, a larger supply space is needed (Fig. 5), and the two spools per position are set opposite one another instead of side by side. The inner end of wire on these spools is brought out and coiled in the head of the spool so that the two spools can be brazed at any time the operator wishes and the wire will be completely used from each spool. Either a stationary flat ring or a rotating type flier can be used for removing the wire. The latter type has certain operating advantages which at present warrant its introduction and use, although the flat disc has so far been used. With the disc type take-off, a tensioning device consisting of a system of three small rollers is used. One roller can be varied in size and as the three come together the slip between them supplies the tension. With the flier type take-off, a tension device is not essential.

Wire Cleaning

In our early efforts to make insulated wire by this process very erratic results were obtained in the continuity of the insulation. It was finally found that small traces of drawing compound left on the wire made it difficult for the wet pulp to adhere to it during the subsequent polishing operations. Therefore, it became necessary to clean all the wire. Con-

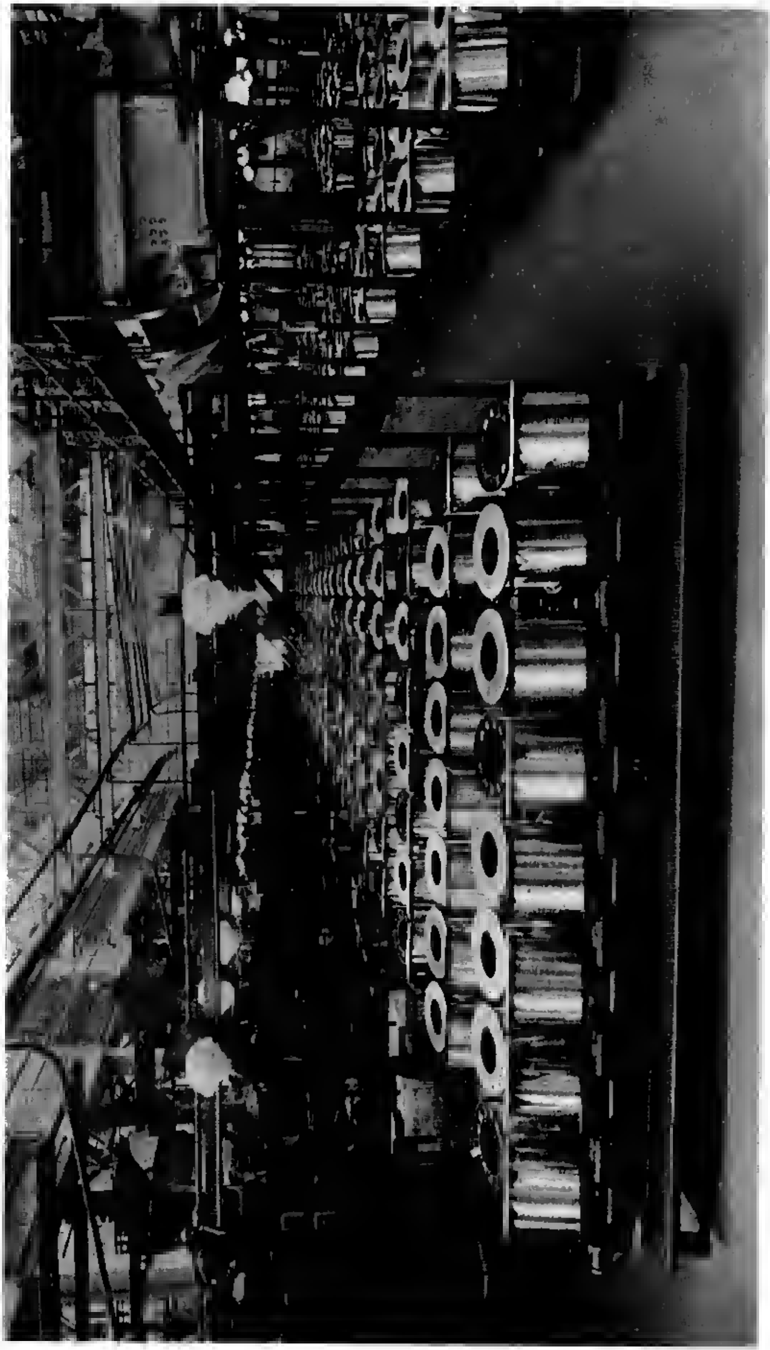

Fig. 5—General view of wire supply

siderable difficulties in designing a suitable cleaner were experienced, but ultimately the use of alternating current together with an alkaline cleaning bath, was found most suitable. The wire passing to the machine comes in contact with the surface of a cleaning solution for a short distance. Electrical contact with the wire is made through guide rolls and the current flows from the wire through the solution to the container. Originally a mixture of cyanides was used as the cleansing agent and the current flow was held to about 8 amperes per square inch surface at 12 volts. Recently a more effective non-poisonous cleansing agent has been developed by using sodium ortho silicate and ivory soap. The passage of the current in either case heats the solution and liberates a rather violent evolution of gas at the surface of the wire. With the soap solution a foam is built up which is continually floated off, carrying the grease, copper, dust, etc. to the sewer. This method keeps the cleaner from concentrating the dirt and consequently eliminates frequent cleaning both of the cleaner and the screen on the cylinder which formerly used to get plugged up with particles of grease carried over from the cleaner by the wire.

Embedding the Wire in the Pulp

From the cleaner the wire is guided into the cylinder machine. It is extremely important at this point that the wire be guided into the center of the small sheets and at such a point on the periphery of the drum that some pulp is deposited below and some over the wire. After passing around the cylinder the wire travels along with the felt and pulp through the presses and finally emerges at the last press embedded in a small sheet of wet paper (Fig. 6). It was found that poor pick-up of the fibers often occurred unless the surface tension of the water was lowered by some means. Ordinary soap is used for this purpose. Approximately ten pounds per thousand pounds of pulp are dissolved in the storage tanks to give effective results and to smooth out the pick-up to give a high degree of uniformity to the weight of pulp per unit length of wire.

Polishing

Polishing of the insulation on the wire is brought about by passing the wire and pulp sheet over polishing blocks which are rotated rapidly around the wire as an axis. Three blocks are used and are so placed that the wire is slightly deflected from its course as it passes first over one block, then the second and finally the last (Fig. 7). The rapid rotation of the polisbing head produces a light rubbing action on the sheet which is rolled down without tearing and results in a good round smooth wrapping of wet paper about the wire. With the wire running at a linear speed of 130 feet per

minute the polishers are rotated at 5000 r.p.m. to give satisfactory insulation.

Drying of the Insulation

The method of drying the insulation is very important. In the early experiments low-temperature air drying, high-temperature air drying and finally moderate-temperature-controlled humidity drying were studied.

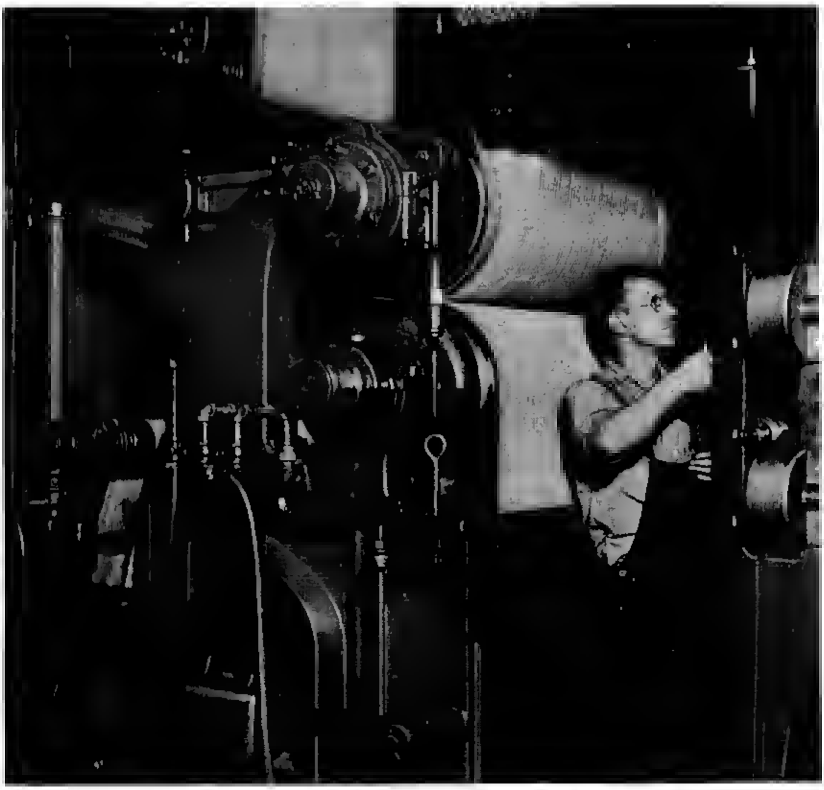

Fig. 6—Wire and pulp from presses

A temperature of about 180°F. and 20% humidity was finally adopted. For a number of years this method was used for experimental cables but it was impossible to get electrostatic capacities below .095 mf. per mi. With such values it appeared that the use of pulp would be strictly limited to certain sizes of wire and certain cables. Study indicated that lack of porosity and close adhesion of the pulp to the wire were large factors in this difficulty and steps were taken to determine what could be done to improve

these values. It was found that by drying the wire at very high speeds by passing it rapidly through high temperatures, the natural shrinkage of the pulp could be greatly reduced and that increased porosity could be obtained. Results on capacitance from such wire were markedly better, and so high-temperature radiant-heat drying was introduced into the process. In this method a box type electric furnace with a heating chamber approximately 26 feet long, 3 feet wide and 8 inches high is used. The wire passes through

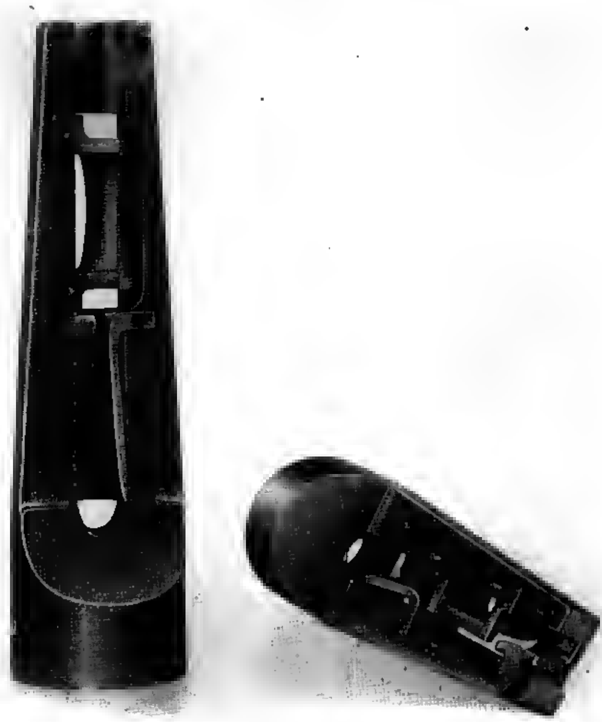

Fig. 7—Individual polisher

this furnace horizontally. In the first third of the furnace 1500°F. is maintained, 1200°F. in the second third, and 800°F. in the last third. The water is literally exploded out of the pulp in this process and leaves a soft porous insulation which is easily stripped from the wire. Electrostatic capacitance values of about .072 mf. per mi. on 24-gauge cables are obtained with this method of drying and improved centering of the wire and roundness of insulation. These values are practically the same as those obtained with wrapped paper. At wire insulating speeds of 140 feet per minute the insu-

lation is dried in approximately 11 seconds. Since in case of a shutdown the wire is immediately burned off, a band of nichrome tape is kept in the furnace at all times so that the wires can be tied to it and carried through for restringing. Broken wires are strung in by tying them to adjacent wires to be carried through.

Reeling up the Finished Wire

Because it is necessary to shift from full to empty spools without shutting down the machine, dual take-up positions are supplied just as dual feed

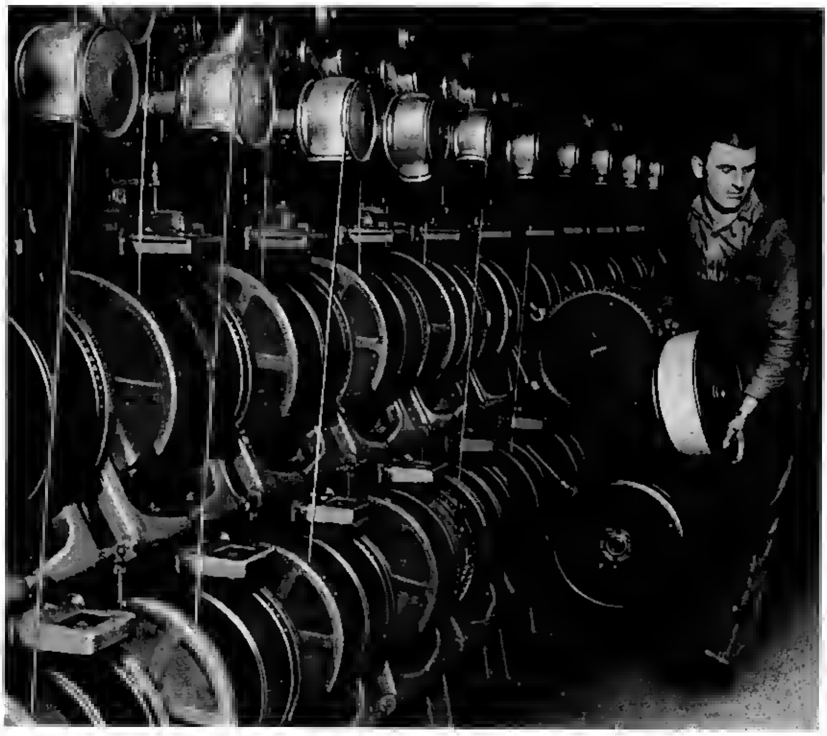

Fig. 8—Insulated wire take-up

positions are used. The take-up spools are rotated through a slipping disc clutch, the pressure on the clutch being controlled by the tension in the wire. Before reaching the take-up spool the wire is passed over a tension drum made up of two capstan pulleys separated by a movable housing enclosing and fastened to a coiled clock spring. By running the wire first around one pulley then reversing it by passing it around a pulley on the spring housing and then around the second capstan pulley any tension variation in the wire causes the spring housing to rotate. The rotation of this housing is com-

municated by a system of rods to the clutch so that it tends to speed up or reduce the speed of the take-up spool. With the long coiled spring wound to a definite tension a predetermined pull on the wire can be maintained. Two spools are driven simultaneously side by side through suitable gears. Each spool, however, is held on a separate arbor which can be pulled out of mesh with the driving gear so that the take-up spool can be stopped and removed. When it is desirable to do this the wire being taken up is simply switched over to the other spool and when a few turns have been taken up the wire between the spools is cut so that the first spool can be removed from the machine (Fig. 8). Sixty spools are run at one time at an average speed of 140 feet per minute or a total wire footage of 8400 feet per minute of running time. Improved beating, better pulp, better cleaning and improved drying and polishing as well as better trained employees in the last few years have greatly improved the product over the original and simplified the control of the process.

Types of Wire Insulated

As mentioned in the first few paragraphs the trend in telephone cable construction has been toward finer and finer wire. The insulating equipment and process described are particularly well adapted to apply coatings of pulp from six to ten mils in thickness to gauges of wire between 19 and 30-gauge. Changes in the mechanical equipment would be necessary for handling wire finer than 30-gauge or wire heavier than 19-gauge. As little demand for these gauges exists in exchange area telephone circuits, no attempt has been made to adapt the machine to these sizes. However, use of the process can be extended quite widely both in the type of materials used for insulating and kind of wire covered, if demand for such extension exists. So far the development of this insulation process has made it possible to produce wires with insulations so thin that 1515-pair cables of 24-gauge wire and 2121-pair cables of 26-gauge wire are now commercially available to the telephone companies with no increase in external diameter of the lead sheath now used. More effective use of existing underground ducts can therefore be made, eliminating possible large expenditures by the telephone companies for such facilities.